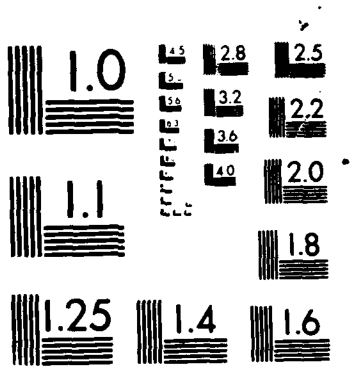
AD-A182 788 ENVIRONMENTAL IMPACT RESEARCH PROGRAM APPLICATION OF THE HABITAT EVALUATI (U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS ENVIR 1/1

UNCLASSIFIED K J KILLGORE ET AL APR 87 WES/MP/EL-87-4 F/G 8/8 NL

END
8-87
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS 1963 A

US Army Corps of Engineers

AD-A182 788

(2)

ENVIRONMENTAL IMPACT
RESEARCH PROGRAM

MISCELLANEOUS PAPER EL-87-4

APPLICATION OF THE HABITAT EVALUATION PROCEDURES IN THE CYPRESS BAYOU BASIN, TEXAS

by

K. Jack Killgore

Environmental Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631, Vicksburg, Mississippi 39180-0631

and

Paul M. Hathorn

US Army Engineer District, Fort Worth
Fort Worth, Texas 76102-0300

April 1987

Final Report

Approved For Public Release; Distribution Unlimited

Prepared for US Army Engineer District, Fort Worth
Fort Worth, Texas 76102-0300

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

AD-A182788

REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0188
Exp Date Jun 30, 1986

1a REPORT SECURITY CLASSIFICATION: Unclassified

1b RESTRICTIVE MARKINGS

2a SECURITY CLASSIFICATION AUTHORITY

2b DECLASSIFICATION / DOWNGRADING SCHEDULE

3 DISTRIBUTION / AVAILABILITY OF REPORT: Approved for public release; distribution unlimited

4 PERFORMING ORGANIZATION REPORT NUMBER(S): Miscellaneous Paper EL-87-4

5 MONITORING ORGANIZATION REPORT NUMBER(S)

6a NAME OF PERFORMING ORGANIZATION: USAEWES Environmental Laboratory

6b OFFICE SYMBOL (If applicable)

7a NAME OF MONITORING ORGANIZATION

6c ADDRESS (City, State, and ZIP Code): PO Box 631, Vicksburg, MS 39180-0631

7b ADDRESS (City, State, and ZIP Code)

8a NAME OF FUNDING / SPONSORING ORGANIZATION: USAED, Fort Worth

8b OFFICE SYMBOL (If applicable)

9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER

8c ADDRESS (City, State, and ZIP Code): PO Box 17300, Fort Worth, Texas 76102-0300

10 SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO	PROJECT NO	TASK NO	WORK UNIT ACCESSION NO

11 TITLE (Include Security Classification): Application of the Habitat Evaluation Procedures in the Cypress Bayou Basin, Texas

12 PERSONAL AUTHOR(S): Killgore, K. Jack; Hathorn, Paul M.

13a TYPE OF REPORT: Final report

13b TIME COVERED: FROM ______ TO ______

14 DATE OF REPORT (Year, Month, Day): April 1987

15 PAGE COUNT: 47

16 SUPPLEMENTARY NOTATION: Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

17 COSATI CODES

FIELD	GROUP	SUB-GROUP

18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number): Compensation, Fishes, Habitat Evaluation, Impact, Lake, River

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

Construction of a dam on either the Little or Black Cypress Bayou, Texas, is being evaluated by the US Army Engineer District, Fort Worth, to provide water resource benefits (flood control, water supply, recreation) in the Cypress Bayou Basin. The Habitat Evaluation Procedure (HEP) was used to determine fish habitat gains in the proposed reservoirs, estimate losses in fish habitat resulting from inundation of portions of the Little and Black Cypress bayous, and recommend methods to compensate for stream habitat losses caused by the project.

Habitat Suitability Index (HSI) models composed of three physical habitat variables (depth, velocity, and cover) were developed from field and literature data for nine species of riverine fishes including: spotted bass, longear sunfish, grass pickerel, flathead catfish, blacktail shiner, ironcolor shiner, brook silverside, spotted sucker, and slough

(Continued)

20 DISTRIBUTION / AVAILABILITY OF ABSTRACT: ☐ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS

21 ABSTRACT SECURITY CLASSIFICATION: Unclassified

22a NAME OF RESPONSIBLE INDIVIDUAL

22b TELEPHONE (Include Area Code)

22c OFFICE SYMBOL

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete

SECURITY CLASSIFICATION OF THIS PAGE

Unclassified

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

19. Abstract (Continued).

cont'd

darter. These species were selected from biological guilds, and they represented 87 percent of the species community. The longear sunfish, grass pickerel, ironcolor shiner, and slough darter preferred shallow, nonflowing water with abundant instream cover, whereas the spotted bass, flathead catfish, blacktail shiner, and spotted sucker liked relatively deeper, fast-flowing water usually associated with large instream objects such as cypress trees and log-jams. The brook silverside was often found in both types of habitat.

Habitat units (HU) were calculated for each species and river at flows ranging from 0 to 1,000 cfs. Trends in the HU-discharge curves were similar for all evaluation species, although the relative amounts of usable fish habitat varied considerably among species. HU's increased with discharge up to approximately 200 cfs, tapered off or slightly decreased, and then increased again at overbank flows. HU discharge curves were similar among species; so to simplify data interpretation, a single composite HU-discharge curve was developed from the average of all species curves and was used in determining baseline habitat and compensation criteria.

Monthly flows that would maintain the historic fish community were identified from the HU discharge curves. In most cases, the maintenance flows corresponded to the 60 percent exceedance value on the monthly flow duration tables. Monthly compensation flows below the proposed damsites were determined to replace fish habitat lost to inundation. Compensation flows during the late winter and spring corresponded to overbank flows (i.e., > 400 cfs), which would replace the majority of fish habitat lost from the project during these months, maximize suitable spawning areas, and ensure fry survival. Compensation flows during the summer and fall months, which are characterized by low flows including prolonged periods when there is no flow in the rivers, ranged from 10 to 100 cfs.

Evaluation of lake habitat was conducted using regression equations based on the standing crop of selected fishes. Habitat gains for four lake species (bluegill, largemouth bass, black crappie, and white bass) as well as total sportfish and total species were determined for both reservoirs. HU's lost due to inundation ranged from 333 to 1,502, whereas HU's gained for total species attributable to the reservoir were 21,741. However, these gains and losses are not considered as in-kind compensation. The lake proposed on the Little Cypress Bayou provided more fish habitat than the Black Cypress Reservoir provided.

Keywords...

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

Preface

This report describes an aquatic resource evaluation of a proposed water resource project in the Cypress Bayou Basin, Texas, and contributes to the overall feasibility study being prepared by the US Army Engineer District, Fort Worth (SWF). Funding for this project was provided by SWF; partial funding for development of the Suitability Index Curves was provided by the Environmental Impact Research Program (Work Unit 32390).

The study was completed by the Aquatic Habitat Group (AHG), Environmental Resources Division (ERD), Environmental Laboratory (EL), US Army Engineer Waterways Experiment Station (WES). The report was prepared by Messrs. K. Jack Killgore (AHG) and Paul M. Hathorn (SWF). Mr. Tom Cloud (US Fish and Wildlife Service, Fort Worth), Mr. Mike Ryan (Texas Parks and Wildlife Department), Dr. Andrew Miller (WES), Dr. William Matthews (University of Oklahoma), Mr. Kenneth Conley (WES), and Mr. Frank Ferguson (WES) contributed to the conduct of this study. The report was prepared under the supervision of Dr. Thomas Wright, Chief, AHG; Dr. Conrad J. Kirby, Chief, ERD; and Dr. John Harrison, Chief, EL. This report was edited by Ms. Lee T. Byrne of the WES Information Technology Laboratory.

COL Allen F. Grum, USA, was the previous Director of WES. COL Dwayne G. Lee, CE, is the present Commander and Director. Dr. Robert W. Whalin is Technical Director.

This report should be cited as follows:

Killgore, K. J., and Hathorn, P. M. 1987. "Application of the Habitat Evaluation Procedure in the Cypress Bayou Basin, Texas," Miscellaneous Paper EL-87-4, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Contents

List of Tables

List of Figures

Conversion Factors, Non-SI to SI (Metric)

Units of Measurement

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
acres	4,046.873	square metres
cubic feet	0.02831685	cubic metres
feet	0.3048	metres
miles (US statute)	1.609347	kilometres
square feet	0.09290304	square metres

Application of the Habitat Evaluation Procedure in the Cypress Bayou Basin, Texas

Introduction

1. The US Army Engineer District, Fort Worth (SWF), is investigating the feasibility of providing flood control, water supply, recreation, and other water resource benefits for the Cypress Bayou Basin, located in northeast Texas. Of the alternative plans considered, construction of a dam on either the Little Cypress Bayou (Marshall Lake) or Black Cypress Bayou (Black Cypress Lake) appears to be the most feasible approach to accommodate the various water resource needs in the basin. Aquatic resource studies of the project were initiated in 1984 by a team of biologists representing SWF, US Fish and Wildlife Service (USFWS), Texas Parks and Wildlife Department (TPWD), and Waterways Experiment Station (WES). A modification of the Habitat Evaluation Procedure (HEP) was applied to evaluate the impacts of the project on aquatic resources. The study approach generally follows the format described in the HEP manual (USFWS 1980) with modifications specific-to-project requirements. An overview of the steps taken in this modified HEP analysis appears in Table 1.

Table 1

Overview of the Steps Taken to Conduct an Aquatic HEP for the Cypress Bayou Basin Project

Step 1:	Delineate the river and future lake habitat and describe the hydraulic and morphometric features.
Step 2:	Select evaluation fish species and construct the Habitat Suitability Index (HSI) models.
Step 3:	Select representative reaches, collect hydraulic and morphometric data, and estimate physical habitat conditions at target discharges using hydraulic mathematical relationships.
Step 4:	Construct habitat duration curves and define maintenance flows.
Step 5:	Determine habitat units lost in the river due to inundation and develop a plan to compensate for lost habitat.
Step 6:	Determine habitat gains of the project created by the reservoirs.

Purpose and Objectives

2. The purpose of this document is to provide SWF with a comprehensive analysis of fish habitat gains and losses resulting from the construction of a dam on either Little or Black Cypress Bayou. The objectives are:

a. To determine baseline stream habitat conditions that would maintain the historic fish community structure.

b. To recommend techniques to compensate for the loss of inundated stream habitat.

c. To identify gains in new fish habitat created by the reservoir.

Methods

Study area

3. The study area included the Little and Black Cypress bayous located in northeastern Texas (Figure 1). Both rivers are lowland, meandering, warmwater streams that are relatively undisturbed by water resource development. The rivers have abundant instream cover such as logjams, rootwads, undercut banks, and cypress trees. Substrate composition is relatively uniform ranging from clayey sand to silty clay. Based on data from the US Geological Survey (USGS) gaging stations located on both rivers near Jefferson, Texas, and field measurements taken throughout the study, water quality (Appendix A) is adequate to sustain viable fish populations at any flow and therefore was not considered in this analysis. The average annual discharge for the Little and Black Cypress bayous is 527 and 333 cfs*, respectively. Discharge ranges from 0 during August through October to greater than 1,000 cfs during the spring months (Appendix B).

4. Three major study areas were used in the HEP: the rivers below the dam sites, the proposed lake areas, and the portion of rivers that would be inundated (Table 2). The river habitats below the dams extend from the damsite downstream to the confluence with the Big Cypress Creek. The river reaches that would be inundated by the project are between the damsite and the conservation pool elevation (US Army Engineer District, Fort Worth (SWF) 1985).

---

* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 4.

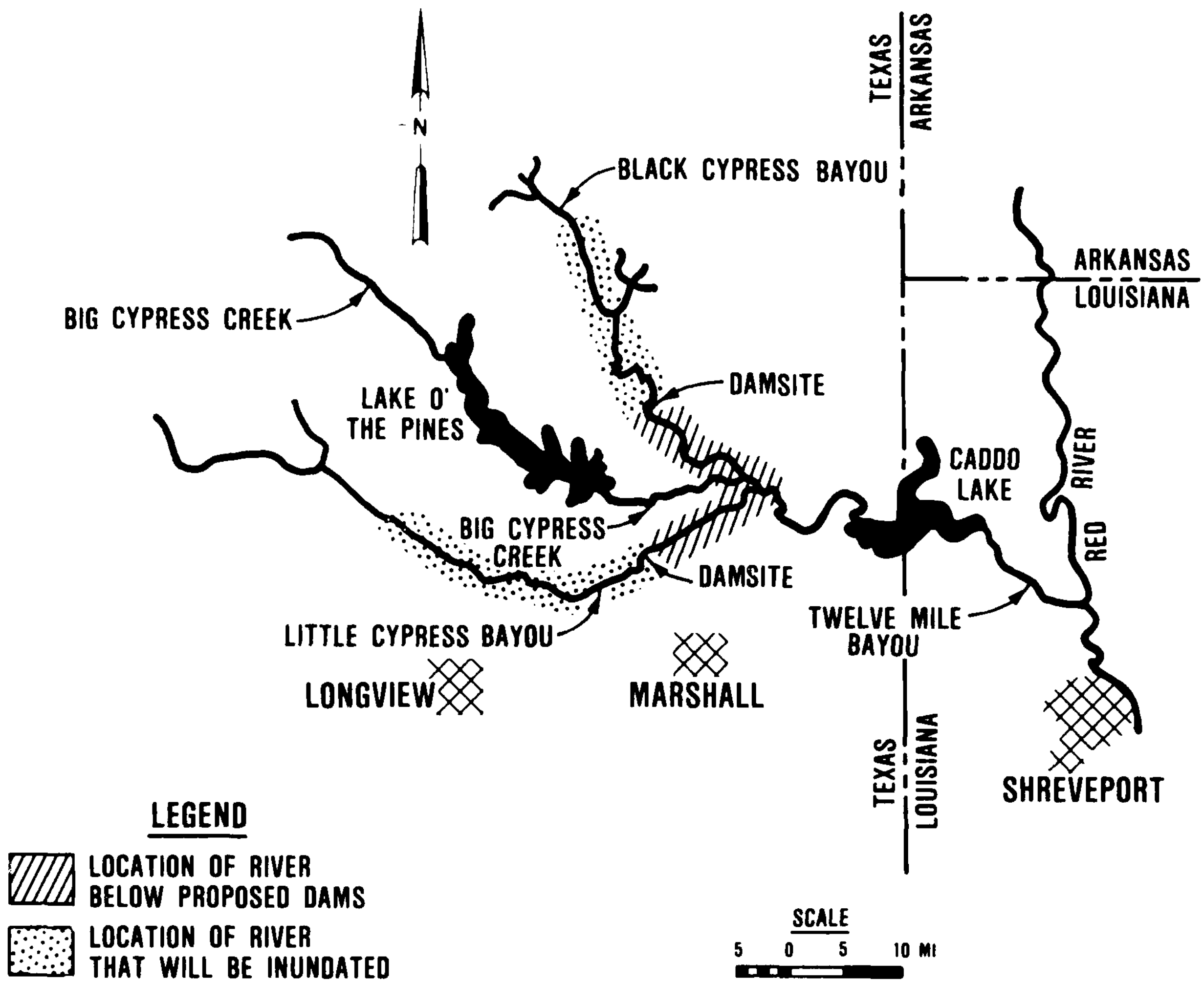


Figure 1. Location of study sites in the Cypress Bayou Basin, Texas

River models

5. From a total of 67 species of fishes known to occur in both rivers (Appendix C), and based upon initial collections by electroshocking, nine evaluation species that were relatively abundant in the study area were chosen. These were spotted bass, grass/chain pickerel, flathead catfish, longear sunfish, spotted sucker, blacktail shiner, ironcolor shiner, brook silverside, and slough darter. These species were selected from biological guilds (Appendix D) that considered adult feeding preferences and reproductive strategies and represented 87 percent of the fish community. All evaluation species were considered to be equally important to the stream ecosystem. A periodicity table (Appendix E) was constructed to relate the presence of life

Table 2

Delineation of River and Lake Habitats for the Little and Black Cypress Bayous

River	Type of Habitat	River Channel miles	Elevation ft	acres
Little Cypress	River below damsite	1-20.3	170-195	646*
	River to be inundated	20.3-41.3	195-255	132**
	Lake (conservation pool)	--	195-255	28,988
Black Cypress	River below damsite	1-17.0	175-200	194*
	River to be inundated	17-44.0	200-253	--
	Lake (conservation pool)	--	200-253	21,951

* Calculated at annual median flow occurring at USGS Gage near Jefferson, Texas.

** Calculated at annual median flow occurring at USGS Gage near Ore City, Texas.

stages (spawning, fry, juvenile, and adults) to changes in discharge and water temperature.

6. The variables used to assess fish habitat in the Little and Black Cypress bayous were depth, velocity, and cover. These physical habitat variables are important because they: (a) regulate the carrying capacity of a river system if water quality is within the tolerance limits of the species, (b) are directly impacted by water resource development, (c) can be manipulated to provide optimum habitat conditions, and (d) are easily measured in the field. Suitability Index (SI) Curves for these variables were developed from field data for all evaluation species except the flathead catfish and slough darter. Curves for these species were developed from the literature.

7. Field-derived SI curves were developed from measurements of water depth, water velocity, and the presence or absence of instream cover at each location where an evaluation species was collected using a boat-mounted electroshocker. Length and weight of each evaluation species were recorded at the time of capture to separate the species into adults, juveniles, and fry.

To the extent possible, an equal amount of time was spent at each type of habitat (channel, side channel, and shoreline). Field data were collected seasonally during flowing water conditions in April, June, and December 1984. Data were also collected in August, when there was no flow in the rivers. However, these data were not used because they were not representative of fish habitat utilization for flowing water conditions. Therefore, a total of 629 observations were made during periods of flowing water. Because of the lack of observations on nonadult life stages (166 observations), the SI curves and HSI models were developed from observations of adult fish habitat utilization (463 observations), only. However, juveniles generally occurred in habitats similar to those of adults. Requirements for spawning and fry survival were accounted for by the occurrence of overbank flows.

8. SI curves were prepared for each evaluation species (Appendix F). The raw field data were grouped into histograms, and the SI curve was drawn through the center of the top of each class interval. These curves summarize the frequency of capture for each of the three habitat variables and for each evaluation species. The Y-axis, or SI score, ranges from 0.0 (no fishes collected) to 1.0 (most frequently utilized) and is a qualitative measure of habitat value. An average HSI score for each species was derived from the geometric mean of all variables using the following formula:

$$\text{HSI} = (V_1 \cdot V_2 \cdot V_3)^{0.333} \qquad (1)$$

where

HSI = Habitat Suitability Index value for physical habitat

V_1 = depth, ft

V_2 = velocity, ft/sec

V_3 = cover, percent

It should be recognized that some bias is inherent when SI curves are developed from observations collected by an electroshocker due to the noise of the generator and boat motor disrupting the normal fish position in the stream and the difficulty in detecting stunned fishes in turbid water. However, this problem is partially accounted for by making a high number of observations.

Lake models

9. The following fishes were evaluated for the proposed lakes: largemouth bass, bluegill, black crappie, white bass, total sport fishes, and total fishes. Predicted standing crops for each species were determined using regression equations prepared by the USFWS (Table 3) and were converted to HSI scores using the technique described in Aggus and Morais (1979).

Field methods--rivers

10. Prior to field sampling, a reconnaissance of both rivers was made by boat, and two representative sites were selected at each river. The sites on the Little Cypress Bayou were located at river mile 2 (Elevation 170 ft, represented 13 river miles) and near the Highway 154 Bridge crossing (Elevation-210 ft, represented 7.3 river miles). Collectively, these two sites represent the stream habitat from the damsite to the mouth of the Little Cypress Bayou (Table 2). Sites on the Black Cypress Bayou were located at river miles 1.5 (Elevation 175 ft, represented 10.5 river miles) and near Berea Bridge crossing (Elevation 200 ft, represented 6.5 river miles). Collectively, these two sites represent the stream habitat from the damsite to the mouth of the Black Cypress Bayou. In addition, the downstream transect at Highway 154 and the upstream transect at Berea Bridge Crossing represented stream habitat above the damsite for the Little Cypress and Black Cypress bayous, respectively. At each site, a metal tag line was positioned across the river at two locations separated by 0.1 mile, and depth, velocity, and cover were measured at regular intervals (number of intervals = 10 percent of the cross-sectional width) that divided the cross section into cells. Water depth was measured to the nearest 0.1 ft using a leveling rod. Water velocity was measured to the nearest 0.1 ft/sec using a Marsh-McBirney model 201 current meter. If the total depth (TD) was less than or equal to 3.0 ft, then velocity was measured at 0.6 TD. If TD exceeded 3.0 ft, then velocity was measured at both 0.2 and 0.8 TD, and an average was obtained. Cover was classified as "present" or "not present" in each cell and converted into the percentage of cells with cover. In addition, the slope and distance from the water's edge to the high- water mark were measured with a hand-held level and tape measure respectively.

Data analysis

11. A noncomputerized method of determining depth, velocity, cover, and other morphometric features of the cross sections at a range of discharges,

Table 3

Summary of Regression Equations and Variables Used to Calculate HSI Values for Lake Evaluation Species

			Lake Habitat Variables							
Species	Regression Equation to Predict Standing Crop	R^2	Lake	Dissolved Solids mg/ℓ	Growing Season days	Outlet Depth ft	Area of Conservation Pool ft^2	Mean Depth ft	Water Level Fluctuation ft	Age years
Largemouth bass	0.5743 - 0.3120 (log water level fluctuations) + 0.2594 (log dissolved solids) + 0.0046 (age)	0.244	Little Cypress (Marshall Lake)	150	213	60	28,988	23	10	1
Bluegill	-821.4815 + 366.5507 (log growing season) - 0.0688 (dissolved solids) + 0.00006 (dissolved solids squared)	0.244	Black Cypress	50	213	60	21,951	20	10	1
Black crappie	2.7778 - 0.0088 (dissolved solids) - 0.00001 (dissolved solids squared)	0.500								
White bass	5.1756 - 0.9512 (log area) - 2.9939 (log mean depth) + 0.0309 (outlet depth) + 1.2550 (log dissolved solids)	0.172								
Total sport fish	0.9809 - 0.0056 (mean depth) + 0.3877 (log mean depth) + 0.9944 (log growing season)	0.094								
Total species	4.9397 + 0.1614 (log area) - 0.0090 (mean depth) - 1.2663 (log growing season) -2×10^{-8} (dissolved solids squared)	0.292								

partially modified from Dunham and Collotzi (1975) and Bovee and Milhous (1978), was used to predict physical habitat conditions at unmeasured flows. The water surface profile measured in the field was plotted on graph paper (Figure 2), and unmeasured hydraulic geometric features of the cross sections were extracted from these graphs in order to calculate velocity and to determine the water depth and percentage of cover for a range of discharges. A detailed description of this procedure for the Little Cypress Bayou is shown in Appendix G.

12. HU's were determined from the following equation:

$$HU = HSI \times Acres \tag{2}$$

where

HSI = Habitat Suitability Index

Acres = Acres of river at a given discharge

HU = Habitat units

This equation was applied to each discharge of interest (10 to 1,000 cfs) for each species at each representative reach. An SI was assigned to the value of each variable (depth, velocity, cover) that occurred at the target discharges. The SI values were aggregated into the HSI model to obtain a value between 0.0 to 1.0 that indicated the suitability of the conditions of depth, velocity, and cover to the evaluation species. The product of the HSI equation was multiplied by the acres of river that occur at each target discharge to obtain HU's. Total HU's for the river were calculated by adding the HU's of the representative reaches for each target discharge.

Results

13. An increase in discharge usually resulted in a positive change in HU's for all species (Figures 3 and 4). HU's increased most rapidly between 0 and 200 cfs, and either tapered off or slightly decreased at discharges greater than 200 cfs. Decreases in HU's were due to high velocities without any substantial addition of cover. HU's increased at overbank flows (i.e., 425 and 460 cfs for the Little and Black Cypress bayous, respectively) because of an increase in cover, shallow depths, and surface area. The Little Cypress Bayou provided more fish habitat than the Black Cypress Bayou provided at all

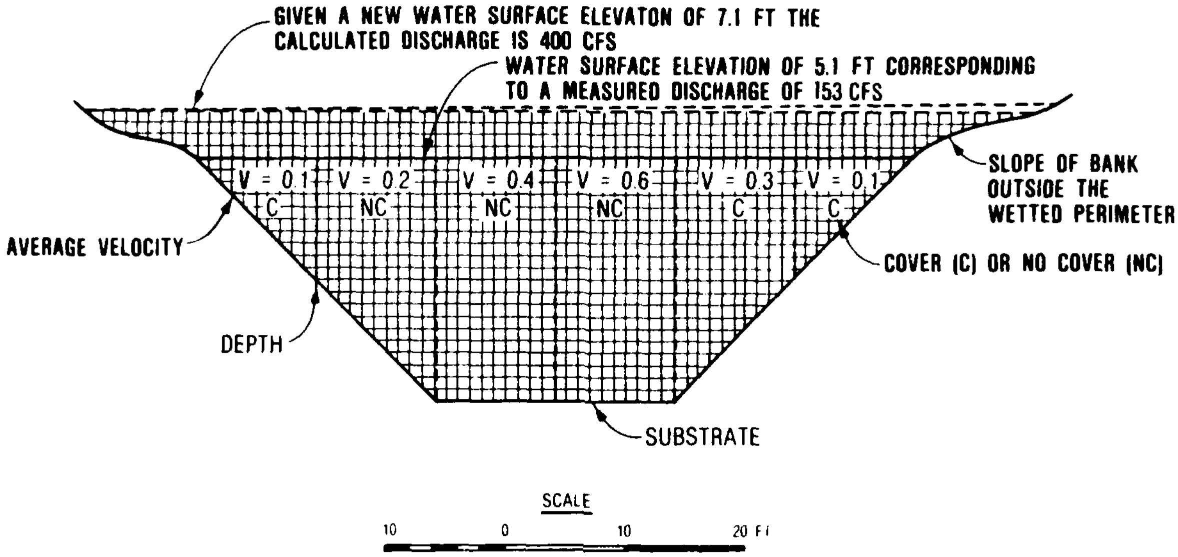


Figure 2. Schematic drawing of procedure to estimate habitat availability for unmeasured flows

discharges. Species that preferred or could tolerate high-velocity, deep water (such as the blacktail shiner, spotted bass, spotted sucker, and flathead catfish) had higher amounts of HU's than did species that usually inhabited shallow, slow-moving water with substantial amounts of instream cover (such as the pickerel, longear sunfish, brook silverside, ironcolor shiner and slough darter). Even though the amounts of HU's were different among species for a given discharge, the trend of the HU discharge curves was similar. Therefore, to simplify data interpretation, a composite HU discharge curve was developed for all nine individual species curves by adding their HU values for each target discharge. These data were then used to recommend maintenance flows and compensation requirements of stream habitat losses (Figures 3 and 4).

14. Maintenance flows have been defined for this study as the positive, inflection point on an HU duration-discharge curve and are considered to be those baseline conditions that would maintain the historic fish community structure for a specific time period below the proposed damsites. An HU duration curve is a cumulative frequency plot that shows the percentage of a certain amount of habitat being equalled or exceeded during a given time

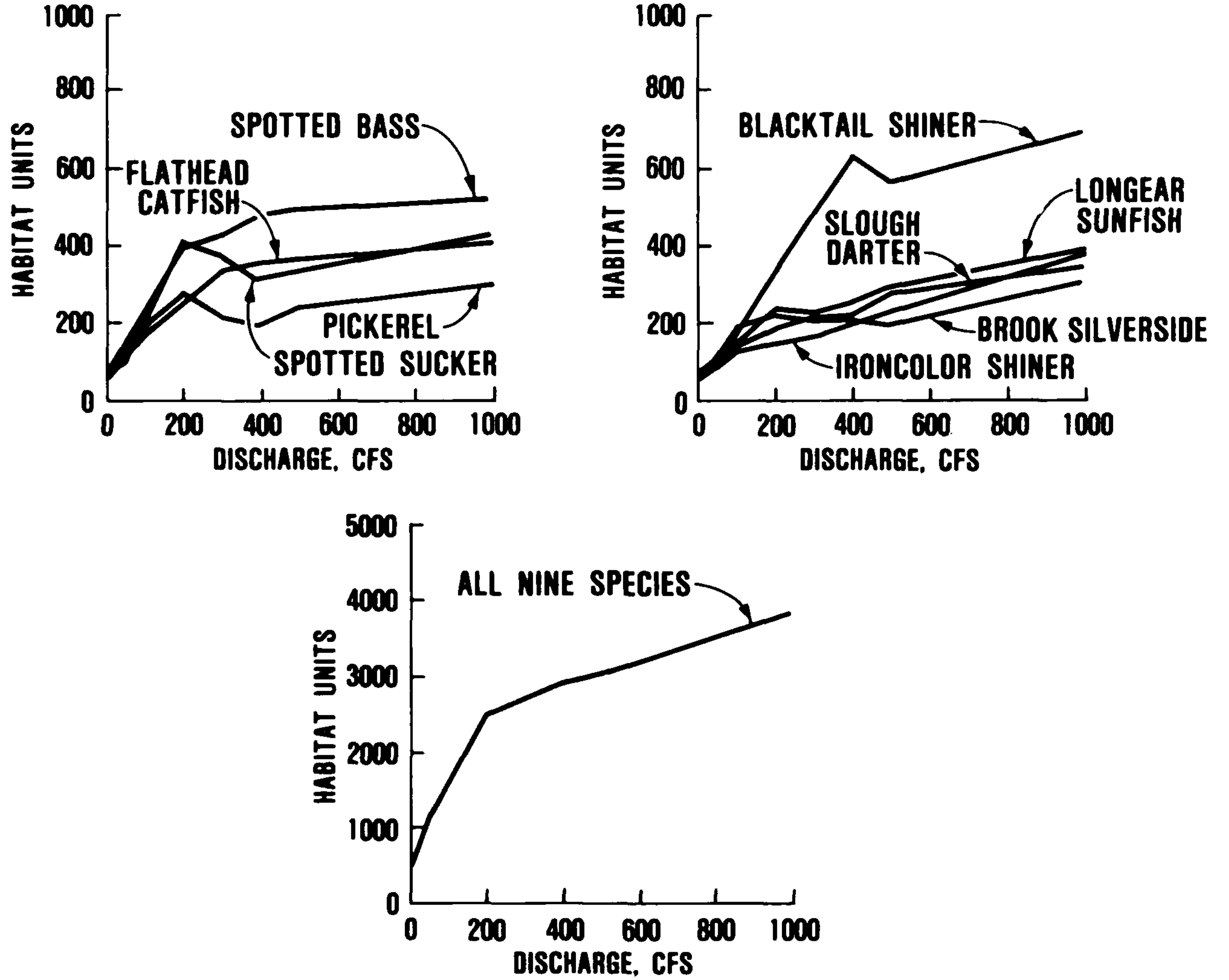


Figure 3. Habitat unit (HU) discharge plots of the evaluation species for the Little Cypress Bayou

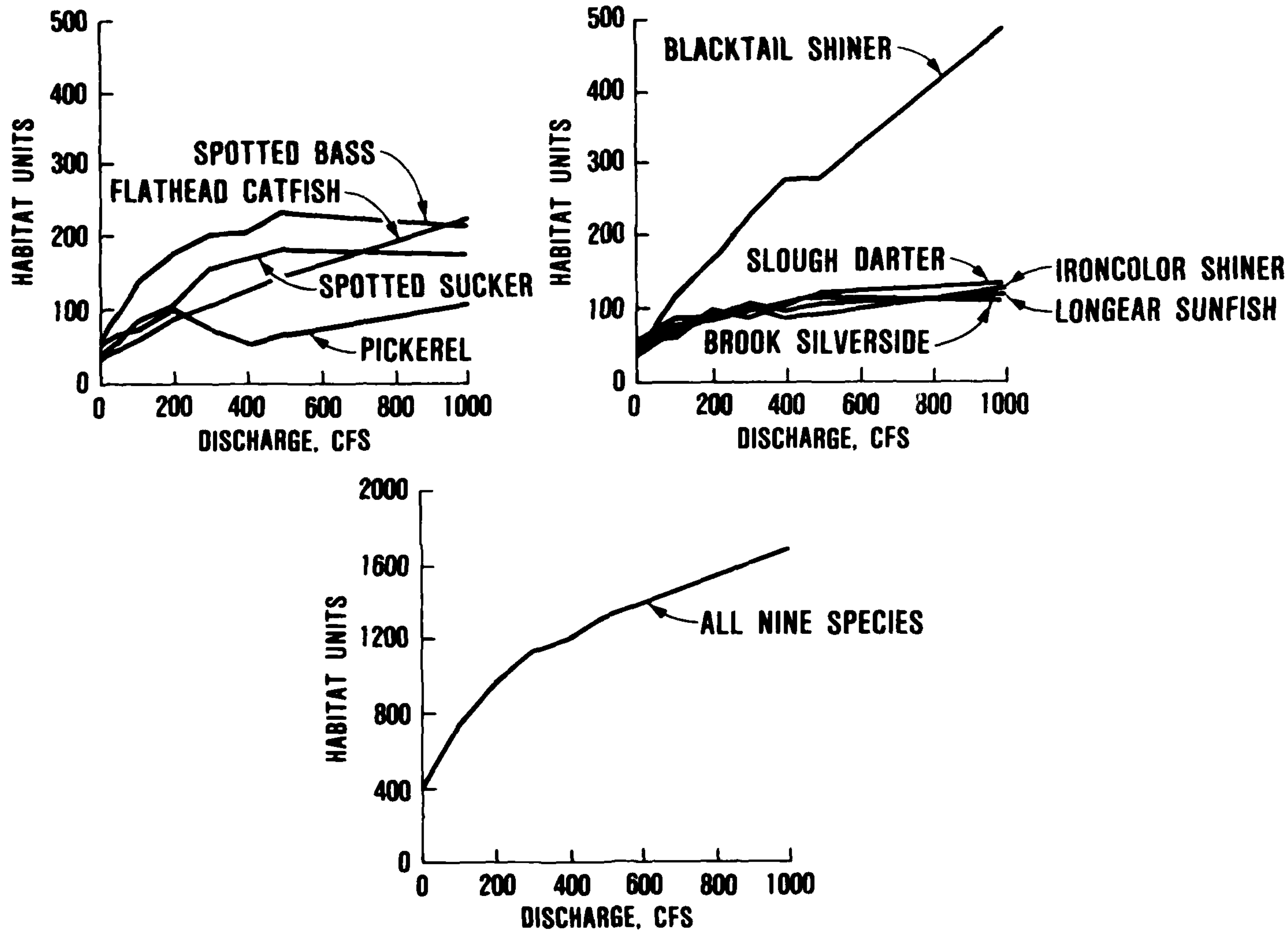


Figure 4. Habitat unit (HU) discharge plots of the evaluation species for the Black Cypress Bayou

period, as described in Bovee (1982). A 10-percent value indicates HU's that occur infrequently, whereas a 90-percent value indicates HU's that occur frequently. For each river, the 10- through 90-percent HU duration values were plotted on the y-axis, and the flows that corresponded with each HU value were indicated on the x-axis (Figures 5 and 6). The inflection points of diminishing increases in HU'S were fairly obvious and were visually interpreted from these figures and from a table of these data (Appendix I). The maintenance flows for most months occurred around the 60-percent HU exceedance value (Table 4). Maintenance flows during the late winter and spring ranged from 190 to 270 cfs in both rivers and declined to near 0 cfs in the summer and early fall.

15. The Little and Black Cypress bayous are classified by USFWS as resource category 2 (in-kind replacement, no trade-offs); therefore, habitat gains from the lake were not included in the compensation analysis. Due to a determination late in the study that a damsite on Black Cypress Bayou was not economically feasible, a compensation plan was conducted for only the Little Cypress Bayou. Loss in HU's at the 50-percent exceedance flow was determined by month to represent the portion of the Little Cypress lost as the result of inundation. The monthly 50-percent exceedance flows were obtained from the USGS gaging station at Highway 259 near Ore City, because it more accurately represented the flows occurring in the overall river segment that would be inundated than did the downstream gaging station (i.e., Highway 59). Furthermore, HSI values and other morphometric features, including acres, that occurred at each median monthly discharge at the USGS gage near Ore City were determined from the Highway 154 downstream transect (see Table G3), which was considered representative of the inundated stream habitat of the Little Cypress Bayou. The total HU's lost at the 50-percent exceedance flow to inundation ranged from 333 to 1,502 depending upon the season (Appendix J). Compensation requirements were determined by calculating the approximate flow that corresponded to the sum of the HU's lost from inundation and the HU's of the maintenance flow using the HU-discharge relationship shown in Appendix H. Based on this analysis, it was determined that compensation flows of 10 to greater than 425 cfs (i.e., overbank flows) would be needed below the dam to achieve full and in-kind compensation for stream habitat lost to inundation (Table 5) and would also serve to maintain the historic fish community from the damsite to the mouth of the Little Cypress Bayou.

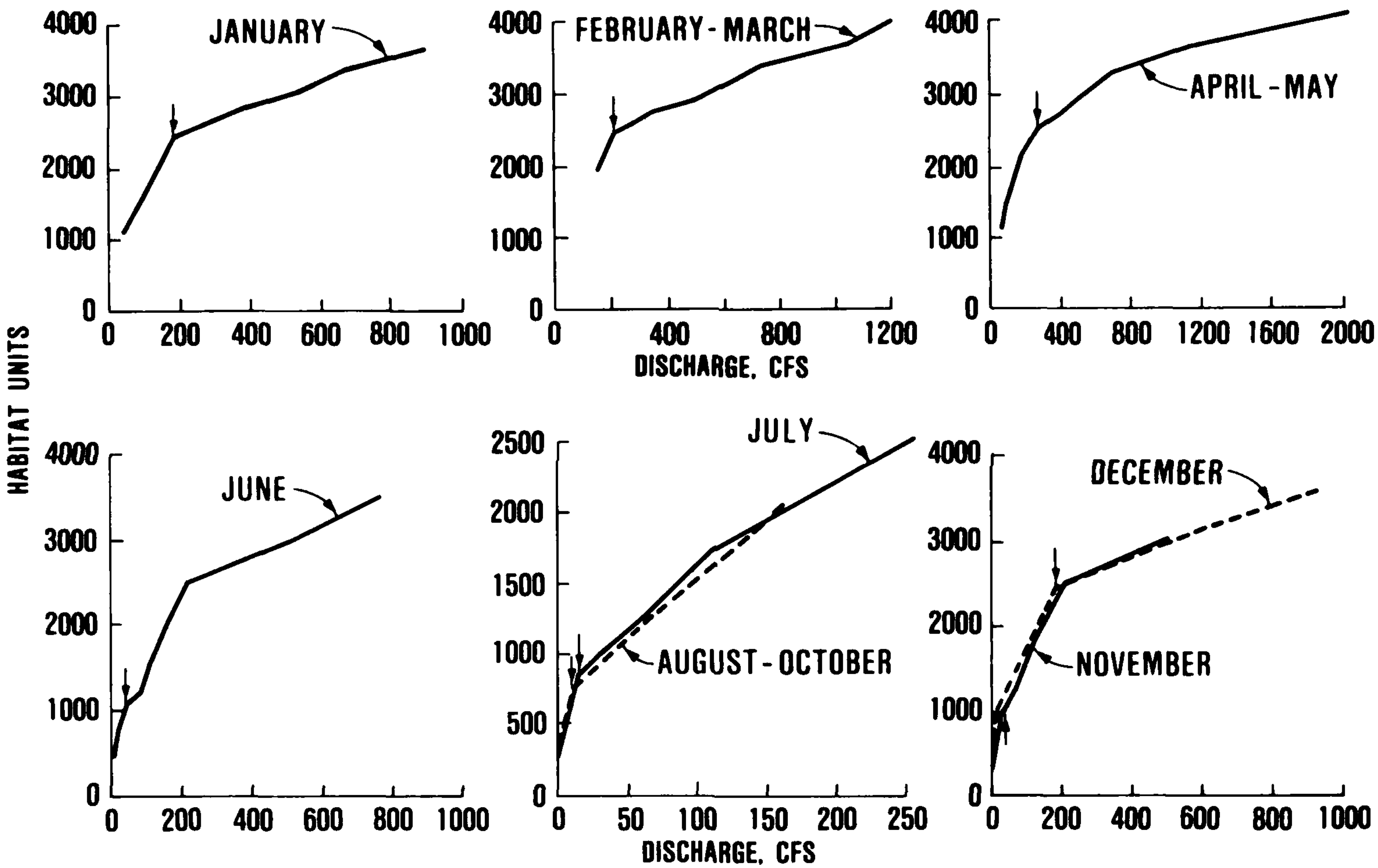


Figure 5. Plots of the habitat unit (HU) duration values and flow for the Little Cypress Bayou. (Arrows indicate the inflection point corresponding to the maintenance flow)

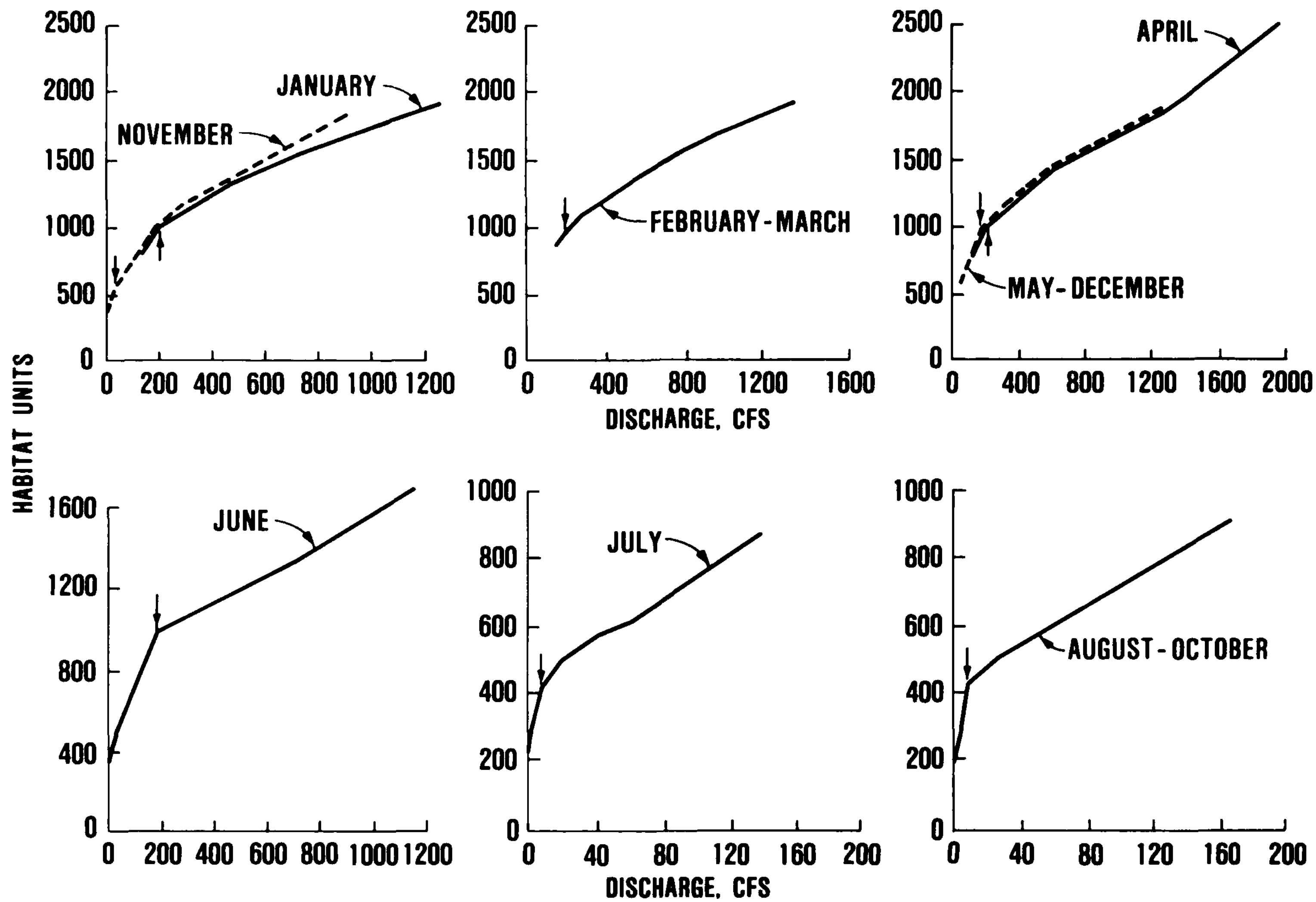


Figure 6. Plots of the habitat unit (HU) duration values and flow for the Black Cypress Bayou. (Arrows indicate the inflection point corresponding to the maintenance flow)

Table 4

Maintenance Flows for the Little and Black Cypress Bayous

Month	Maintenance Flow, cfs	
	Little Cypress Bayou	Black Cypress Bayou
January	190	190
February	215	210
March	215	270
April	270	210
May	270	180
June	40	55
July	14	7
August	3	3
September	3	3
October	3	3
November	16	65
December	55	180

16. An aquatic HEP was conducted for the proposed Marshall and Black Cypress lakes (Table 6). The analysis includes a 10-year period beginning immediately after dam closure and assumes that the physical and chemical variables used in the lake HSI models (Table 3) would not significantly change during this time period. Marshall Lake had the highest amount of habitats for all species except bluegill. These data were prepared to define habitat gains from the project and were not intended to facilitate trade-off analysis for stream habitat losses. With either lake, however, these gains would occur and should be considered as intangible benefits of the lake, possibly for out-of-kind mitigation for lower resource categories. These values can also be used in determination of economic man-days (recreation) benefits attributable to the lake project.

Discussion

17. Rivers in the Cypress Bayou Basin undergo extreme seasonal water level fluctuations. Summer drought accompanied by high-water temperatures and

Table 5

Compensation Flows for the Little Cypress Bayou

Month	Maintenance Flow Below the Dam cfs	Maintenance Flow Below the Dam HU's	Monthly Median Flow at USGS Gage near Ore City	Habitat Units Lost Due to Inundation	Compensation Requirements cfs	Compensation Requirements HU's
January	190	2,420	149	1,011	>425*	>3,000
February	215	2,500	253	1,448	>425*	>3,000
March	215	2,500	298	1,502	>425*	>3,000
April	270	2,600	206	1,212	>425*	>3,000
May	270	2,600	193	876	>425*	>3,000
June	40	1,010	45	487	100	1,500
July	14	850	6	314	50	1,170
August	3	400	2	333	10	730
September	3	400	2	333	10	730
October	3	400	3	333	10	730
November	16	990	33	442	85	1,430
December	55	1,110	92	760	150	1,870

* Overbank flows.

low dissolved oxygen (see Appendix A) drastically decreases usable fish habitat. These conditions can increase spatial competition for food and habitat (Cowx, Young, and Hellawell 1984) and can also increase foraging efficiency by predators because of clear water and concentrated prey (Stevens and Miller 1983). In contrast, high flows during spring increase usable fish habitat and ensure adequate spawning, survival, and nursery habitat for fishes. Instream flow releases, particularly during the summer drought, would moderate standing crop fluctuations in downstream reaches and compensate for in-kind habitat lost from inundation.

18. The HEP is a flexible procedure to assess changes in habitat from water resource projects. A variety of species-oriented assessment techniques have been developed that are conceptually similar to HEP but differ in expertise (training) requirements, time and resource constraints, data requirements, and objectives pursued (Schuytema 1982, Coulombe 1978). The HEP is

Table 6

Average Annual Habitat Units (HU's) of Lake Species for Marshall and Black Cypress Lakes During the Time Period of 1 to 10 Years

Lake	Species	Area of Habitat acres	Habitat Suitability Index	Average Annual HU's
Marshall Lake (Little Cypress)	All Species	28,988	0.75	21,741
	Bluegill	28,988	0.45	13,045
	Largemouth Bass	28,988	0.40	11,595
	Black Crappie	28,988	0.50	14,494
	White Bass	28,988	0.78	22,610
	Sportfish	28,988	0.58	16,813
Black Cypress Lake	All Species	21,951	0.77	16,902
	Bluegill	21,951	0.71	15,585
	Largemouth Bass	21,951	0.35	7,683
	Black Crappie	21,951	0.62	13,609
	White Bass	21,951	0.65	14,268
	Sportfish	21,951	0.55	12,073

ideally suited for analyzing lake habitat, although limited by one's ability to predict future habitat conditions. This method is specifically tailored to facilitate trade-off analysis and to develop compensation plans. The HEP, as modified for this study, was selected to analyze river habitat to minimize the requirements for data acquisition and analysis as well as to provide a quantitative and relatively rapid approach in determining changes in fish habitat as a function of flow. An important advantage in using the hydraulic procedures described in this report was the ability to extrapolate the amount of usable fish habitat to a flow range of 0 to 1,000 cfs in a relatively short time. Six working days were required to complete the river analysis, including the collection of field data (physical habitat), and to determine maintenance plus compensation flows.

Conclusions and Recommendations

19. Usable habitat for nine species of fish increased with discharge up to 200 cfs, moderated or decreased at flows from 200 to 400 cfs, and again increased at overbank flows.

20. The longear sunfish, ironcolor shiner, grass/chain pickerel, and slough darter preferred shallow, slow-moving water with abundant instream cover, whereas the spotted bass, blacktail shiner, spotted sucker, and flathead catfish liked deeper water with moderate to fast flow usually associated with large instream objects such as cypress trees and logjams. The brook silverside was found in both types of habitat.

21. To maintain the status quo of the fish community structure below the proposed damsite, the monthly maintenance flows that appear in Table 5 should be released. However, these flows do not mitigate for losses of stream habitat caused by inundation.

22. To compensate for the inundated fish habitat, the compensation flows that appear in Table 6 should be released. Overbank flows should be released periodically during the spring spawning season to maximize spawning areas and to ensure fry survival.

23. Marshall Lake will create more fish habitat than will Black Cypress Lake.

References

Aggus, L. R., and Morais, D. I. 1979. "Habitat Suitability Index Equations for Reservoirs Based on Standing Crop of Fish," US Fish and Wildlife Service, Fort Collins, Colo.

Bovee, K. D. 1982. "A Guide to Stream Habitat Analysis Using the Instream Flow Incremental Methodology," Instream Flow Information Paper No. 12, FWS/OBS-82/26, US Fish and Wildlife Service, Fort Collins, Colo.

Bovee, K. D., and Milhous, R. 1978. "Hydraulic Simulation in Instream Flow Studies: Theory and Techniques," Instream Flow Information Paper: No. 5, FWS/OBS-78/33, US Fish and Wildlife Service, Fort Collins, Colo.

Coulombe, H. N. 1978 (Jan.). "Toward an Integrated Ecological Assessment of Wildlife Habitat," National Workshop of Integrated Inventories of Renewable National Resources, Tucson, Ariz.

Cowx, I. G., Young, W. O., and Hellawell, J. M. 1984. "The Influence of Drought on the Fish and Invertebrate Populations of an Upland Stream in Wales," Freshwater Biology, Vol 14, pp 165-177.

Dunham, D. K., and Collotzi, A. 1975. "The Transect Method of Stream Habitat Inventory," US Forest Service, Ogden, Utah.

Grossman, G. D. 1982. "Dynamics and Organization of a Rocky Intertidal Fish Assemblage: the Persistence and Resilience of Taxocene Structure," American Naturalist, Vol 119, pp 611-637.

Henderson, F. M. 1966. Open Channel Flow, MacMillan Co., New York.

Ross, R. T., Matthews, W. J., and Echelle, A. A. 1985. "Persistence of Stream Fish Assemblages: Effects of Environmental Change," The American Naturalist, Vol 126, No. 1, j 24-40.

Schuytema, G. S. 1982. "A Review of Aquatic Habitat Assessment Methods," EPA-600/3-82-002, US Environmental Protection Agency, Corvallis, Oreg.

Stevens, D. E., and Miller, L. E. 1983. "Effects of River Flow on Abundance of Young Chinook Salmon, American Shad, Longfin Smelt, and Delta Smelt in the Sacramento-San Joaquin River System," North American Journal of Fisheries Management, Vol 3, pp 425-437.

US Army Engineer District, Fort Worth (SWF). 1985. "Cypress Bayou Basin Feasibility Study-Formulation," Fort Worth, Texas.

US Fish and Wildlife Service (USFWS). 1980. "Habitat Evaluation Procedures," ESM 102, Fort Collins, Colo.

Appendix A: Summary of Water Quality Variables in the Cypress Bayou Basin, Texas

River/Month	Conductivity µmho/cm	Temperature °C	Total Dissolved Solids mg/ℓ	Dissolved Oxygen mg/ℓ	Turbidity JTU
Little Cypress Bayou					
January	178 ± 58(11)	5.9 ± 2.6(11)	110 ± 30(11)	10.9 ± 0.8(7)	8.0 ± 5.0(4)
February	186 ± 54(6)	8.0 ± 3.4(6)	110 ± 25(6)	8.7 ± 1.7(3)	--
March	153 ± 43(9)	15.4 ± 1.7(9)	94 ± 25(9)	7.2 ± 1.1(5)	6.0 ± 1.7(3)
April	146 ± 56(8)	17.7 ± 1.8(8)	86 ± 30(8)	6.9 ± 0.9(6)	15.0 ± 2.8(2)
May	185 ± 99(8)	22.2 ± 1.5(7)	111 ± 56(8)	6.1 ± 0.3(4)	26.0 ± 1.4(2)
June	150 ± 76(7)	24.7 ± 2.4(7)	93 ± 45(7)	5.5 ± 1.3(7)	14.0 ± 12.7(2)
July	207 ± 59(8)	27.5 ± 1.5(8)	125 ± 26(8)	4.3 ± 1.1(5)	23.5 ± 10.6(2)
August	296 ± 206(9)	27.1 ± 2.3(9)	213 ± 148(9)	5.2 ± 0.6(5)	24.0 ± 25.4(2)
September	182 ± 55(8)	24.5 ± 2.9(7)	109 ± 29(8)	5.4 ± 0.7(4)	14.0(1)
October	220 ± 82(9)	17.5 ± 3.0(9)	127 ± 47(9)	6.9 ± 1.6(5)	5.0(1)
November	225 ± 91(9)	11.3 ± 4.0(9)	133 ± 48(9)	8.8 ± 2.4(4)	7.5 ± 0.7(2)
December	189 ± 104(9)	8.5 ± 2.1(9)	109 ± 54(9)	9.9 ± 2.0(4)	--
Black Cypress Bayou					
January	52 ± 4(5)	7.6 ± 1.1(4)	45 ± 4(5)	--	--
February	56 ± 11(7)	8.2 ± 4.3(7)	45 ± 8(7)	--	--
March	57 ± 15(4)	16.6 ± 0.7(4)	42 ± 5(4)	--	--
April	56 ± 12(6)	16.1 ± 4.3(6)	43 ± 9(6)	--	--
May	53 ± 11(6)	20.2 ± 1.7(6)	43 ± 10(6)	--	--
June	62 ± 15(8)	25.1 ± 2.5(8)	48 ± 10(8)	--	--
July	69 ± 14(7)	27.4 ± 1.8(7)	50 ± 5(7)	--	--
August	86 ± 34(6)	26.8 ± 2.4(6)	58 ± 15(6)	--	--
September	86 ± 41(3)	28.3 ± 3.5(3)	63 ± 19(3)	--	--
October	63 ± 8(6)	18.4 ± 4.1(6)	50 ± 4(6)	--	--
November	82 ± 62(7)	10.2 ± 3.4(7)	59 ± 28(7)	--	--
December	59 ± 18(5)	7.7 ± 3.8(5)	46 ± 14(4)	--	--

Appendix B: Flow Duration Table for the Little and Black Cypress Bayous, Texas

Site/Percent Exceedance	Discharge by Month, cfs											
	January	February	March	April	May	June	July	August	September	October	November	December
					Little Cypress Bayou*							
10	1,560	1,750	1,950	2,070	2,430	1,090	352	100	226	251	801	1,360
20	1,010	1,300	1,430	1,320	1,520	618	158	43	84	111	300	853
30	782	997	1,060	941	1,030	315	95	27	38	49	159	511
40	581	807	870	702	720	194	54	17	21	31	104	317
50	409	658	689	555	531	135	30	9	9	15	72	227
60	277	543	546	413	371	89	18	4	2	6	47	163
70	205	407	411	282	238	54	11	1	0	1	23	112
80	120	245	289	192	135	30	4	0	0	0	8	72
90	70	131	192	113	85	14	1	0	0	0	0	45
n	1,178	1,074	1,178	1,140	1,178	1,170	1,209	1,209	1,170	1,178	1,140	1,178
					Black Cypress Bayou*							
10	919	952	1,390	1,560	1,010	737	147	74	221	220	530	962
20	696	760	956	919	675	391	75	29	27	86	292	636
30	531	645	761	614	473	245	49	16	12	44	187	457
40	399	546	632	456	336	167	35	9	6	21	117	324
50	307	465	510	340	244	121	21	5	2	11	78	231
60	236	384	394	256	179	72	8	2	0	3	49	169
70	182	312	321	208	138	40	3	1	0	1	31	133
80	194	237	253	159	99	16	1	0	0	0	13	100
90	111	161	187	102	51	4	0	0	0	0	4	75
n	496	452	496	480	496	480	496	496	480	527	480	496

* Flow calculated from USGS gages at Highway 59 near Jefferson, Texas.

Appendix C: Fish Species List of the Little and Black Cypress Bayous, Texas

Checklist of Fish Species Collected from the Little and Black Cypress Rivers, Texas. Collected by Ryan, Matthews, Killgore (1984) - 0; collected by Kemp (1954) - X; not collected - NC

Common Name	Species	Little Cypress	Black Cypress
Chestnut lamprey	*Ichthyomyzon castaneus*	X	NC
Spotted gar	*Lepisosteus oculatus*	0	NC
Longnose gar	*Lepisosteus osseus*	X	NC
Bowfin	*Amia calva*	0	0
Gizzard shad	*Dorosoma cepedianum*	0	0
Grass pickerel	*Esox americanus vermiculatus*	0	0
Chain pickerel	*Esox niger*	0	0
Black buffalo	*Ictiobus niger*	X	NC
Smallmouth buffalo	*Ictiobus bubalus*	X	NC
Spotted sucker	*Minytrema melanops*	0	0
Common carp	*Cyprinus* ·*arpio*	0	0
Golden shiner	*Notemigonus crysoleucas*	0	X
Pugnose minnow	*Notropis emiliae*	0	0
Emerald shiner	*Notropis atherinoides*	0	X
Ribbon shiner	*Notropis fumeus*	0	0
Redfin shiner	*Notropis umbratilis*	0	0
Ironcolor shiner	*Notropis chalybaeus*	0	0
Weed shiner	*Notropis texanus*	0	0
Pallid shiner	*Notropis amnis*	0	0
Blacktail shiner	*Notropis venustus*	0	0
Red shiner	*Notropis lutrensis*	X	NC
Sand shiner	*Notropis stramineus*	X	NC
Blackspot shiner	*Notropis atrocaudalis*	X	X
Silvery minnow	*Hybognathus nuchalis*	X	X
Cypress minnow	*Hybognathus hayi*	X	X

(Continued)

(Sheet 1 of 3)

(Continued)

Common Name	Species	Little Cypress	Black Cypress
Bullhead minnow	*Pimephales vigilax*	X	0
Channel catfish	*Ictalurus punctatus*	0	0
Black bullhead	*Ictalurus melas*	0	X
Yellow bullhead	*Ictalurus natalis*	0	X
Flathead catfish	*Pylodictis olivaris*	0	0
Tadpole madtom	*Noturus gyrinus*	0	0
American eel	*Anguilla rostrata*	0	0
Golden topminnow	*Fundulus chrysotus*	0	X
Starhead topminnow	*Fundulus blairae*	0	X
Blackstripe topminnow	*Fundulus notatus*	0	X
Blackspotted topminnow	*Fundulus olivaceous*	0	0
Mosquitofish	*Gambusia affinis*	0	0
Pirate perch	*Aphredoderus sayanus*	0	0
Brook silversides	*Labidesthes sicculus*	0	0
White bass	*Morone chrysops*	0	0
Yellow bass	*Morone mississippiensis*	0	NC
Spotted bass	*Micropterus punctulatus*	0	0
Largemouth bass	*Micropterus salmoides*	0	0
Warmouth	*Lepomis gulosus*	0	0
Green sunfish	*Lepomis cyanellus*	0	NC
Spotted sunfish	*Lepomis punctatus*	0	0
Bantam sunfish	*Lepomis symmetricus*	NC	X
Redear sunfish	*Lepomis microlophus*	0	0
Bluegill	*Lepomis macrochirus*	0	0
Orangespotted sunfish	*Lepomis humilis*	NC	X
Redbreast sunfish	*Lepomis auritus*	NC	X
Longear sunfish	*Lepomis megalotis*	0	0
Dollar sunfish	*Lepomis marginatus*	X	X
White crappie	*Pomoxis annularis*	0	0
Black crappie	*Pomoxis nigromaculatus*	0	0

(Continued)

(Sheet 2 of 3)

(Concluded)

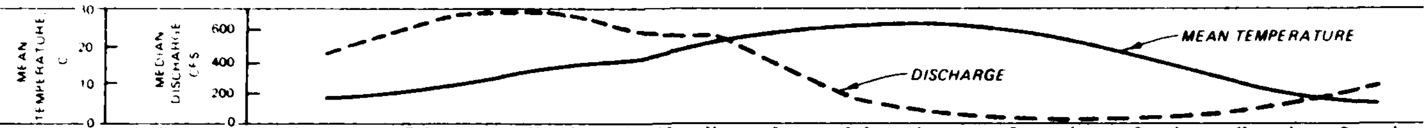
Common Name	Species	Little Cypress	Black Cypress
Flier	*Centrarchus macropterus*	NC	0
Banded pygmy sunfish	*Elassoma zonatum*	0	X
Black side darter	*Percina maculata*	0	0
Dusky darter	*Percina sciera*	NC	X
Log perch	*Percina caprodes*	NC	0
Scaly sand darter	*Ammocrypta vivax*	NC	X
Bluntnose darter	*Etheostoma chlorosomum*	0	0
Slough darter	*Etheostoma gracile*	0	X
Mud darter	*Etheostoma asprigene*	0	NC
Cypress darter	*Etheostoma proeliare*	0	0
Redfin darter	*Etheostoma whipplei*	0	NC
Freshwater drum	*Aplodinotus grunniens*	0	0
Totals	67 species	60	56

(Sheet 3 of 3)

Appendix D: Feeding and Reproductive Guild of Fishes in Cypress Bayou Basin, Texas

ADULT FOOD PREFERENCE	REPRODUCTIVE STRATEGY: Nonguarders - No Nest Constructed: Pelagophils	Nonguarders - No Nest Constructed: Litho-phytophils	Nonguarders - No Nest Constructed: Speleophils	Guarders - Nest Spawners: Litho-phytophils	Guarders - Nest Spawners: Spelophils	Bearers: External	Bearers: Internal
Piscivores	*Aplodinotus grunniens*	*Lepisosteus oculatus* *Lepisosteus osseus* *Morone chrysops* *Morone mississippiensis* *Esox vermiculatus* *Esox niger*		*Pylodictis olivaris* *Amia calva* *Micropterus salmoides* *Micropterus punctulatus* *Pomoxis annularis* *Pomoxis nigromaculatus*			
Planktivores and open water insectivores	*Notropis atherinoides*	*Dorosoma cepedianum* *Notemigonus crysoleucas* *Hybognathus nuchalis* *Hybognathus hayi* *Fundulus chrysotus* *Fundulus olivaceus* *Fundulus blairae* *Fundulus notatus* *Labidesthes sicculus* *Notropis emiliae* *Notropis fumeus* *Notropis texanus*	*Notropis venustus* *Notropis lutrensis* *Notropis umbratilus*	*Elassoma zonatum*	*Pimephales vigilax*	*Aphredoderus sayanus*	*Gambusia affinis*
Benthos feeders		*Notropis stramineus* *Notropis chalybaeus* *Notropis amnis* *Notropis atrocaudalis* *Percina caprodes* *Percina maculata* *Percina sciera* *Ammocrypta vivax*	*Etheostoma chlorosomum* *Etheostoma gracile* *Etheostoma asprigene* *Etheostoma proeliare* *Etheostoma whipplei*	*Ictalurus melas* *Centrarchus macropterus* *Lepomis auritus* *Lepomis cyanellus* *Lepomis macrochirus* *Lepomis megalotis* *Lepomis humilis* *Lepomis marginatus* *Lepomis punctatus* *Lepomis symmetricus* *Lepomis gulosus* *Lepomis microlophus*	*Ictalurus natalis* *Ictalurus punctatus* *Noturus gyrinus*		
Detritivores		*Cyprinus carpio* *Ictiobus niger* *Ictiobus bubalus* *Minytrema melanops*					

Appendix E: Monthly Periodicity of Evaluation Species Relative to Temperature and Discharge



Species	Life Stage	January	February	March	April	May	June	July	August	September	October	November	December
Grass/chain pickerel	Spawning		X	X									
	Fry		X	X	X								
	Juvenile	X	X	X		X	X	X	X	X	X	X	X
	Adult	X	X	X	X	X	X	X	X	X	X	X	X
Ironcolor shiner	Spawning				X	X	X	X					
	Fry				X	X	X	X	X				
	Juvenile	X	X	X		X	X	X	X	X	X	X	X
	Adult	X	X	X	X	X	X	X	X	X	X	X	X
Blacktail shiner	Spawning				X	X	X						
	Fry				X	X	X	X					
	Juvenile	X	X	X		X	X	X	X	X	X	X	X
	Adult	X	X	X	X	X	X	X	X	X	X	X	X
Spotted sucker	Spawning				X	X							
	Fry				X	X	X	X					
	Juvenile	X	X	X	X	X	X	X	X	X	X	X	X
	Adult	X	X	X	X	X	X	X	X	X	X	X	X
Flathead catfish	Spawning					X	X						
	Fry					X	X	X					
	Juvenile	X	X	X	X	X	X	X	X	X	X	X	X
	Adult	X	X	X	X	X	X	X	X	X	X	X	X
Brook silverside	Spawning				X	X	X						
	Fry				X	X	X						
	Juvenile					X	X	X	X	X			
	Adult	X	X	X	X	X	X	X	X	X	X	X	X
Spotted bass	Spawning			X	X	X							
	Fry				X	X	X						
	Juvenile	X	X	X	X	X	X	X	X	X	X	X	X
	Adult	X	X	X	X	X	X	X	X	X	X	X	X
Longear sunfish	Spawning					X	X	X	X				
	Fry						X	X	X	X			
	Juvenile	X	X	X	X		X	X	X	X	X	X	X
	Adult	X	X	X	X	X	X	X	X	X	X	X	X
Slough darter	Spawning			X	X								
	Fry			X	X	X	X						
	Juvenile	X	X	X	X		X	X	X	X	X	X	X
	Adult	X	X	X	X	X	X	X	X	X	X	X	X

Appendix F: Suitability Index Curves for the Nine Evaluation Riverine Fish Species

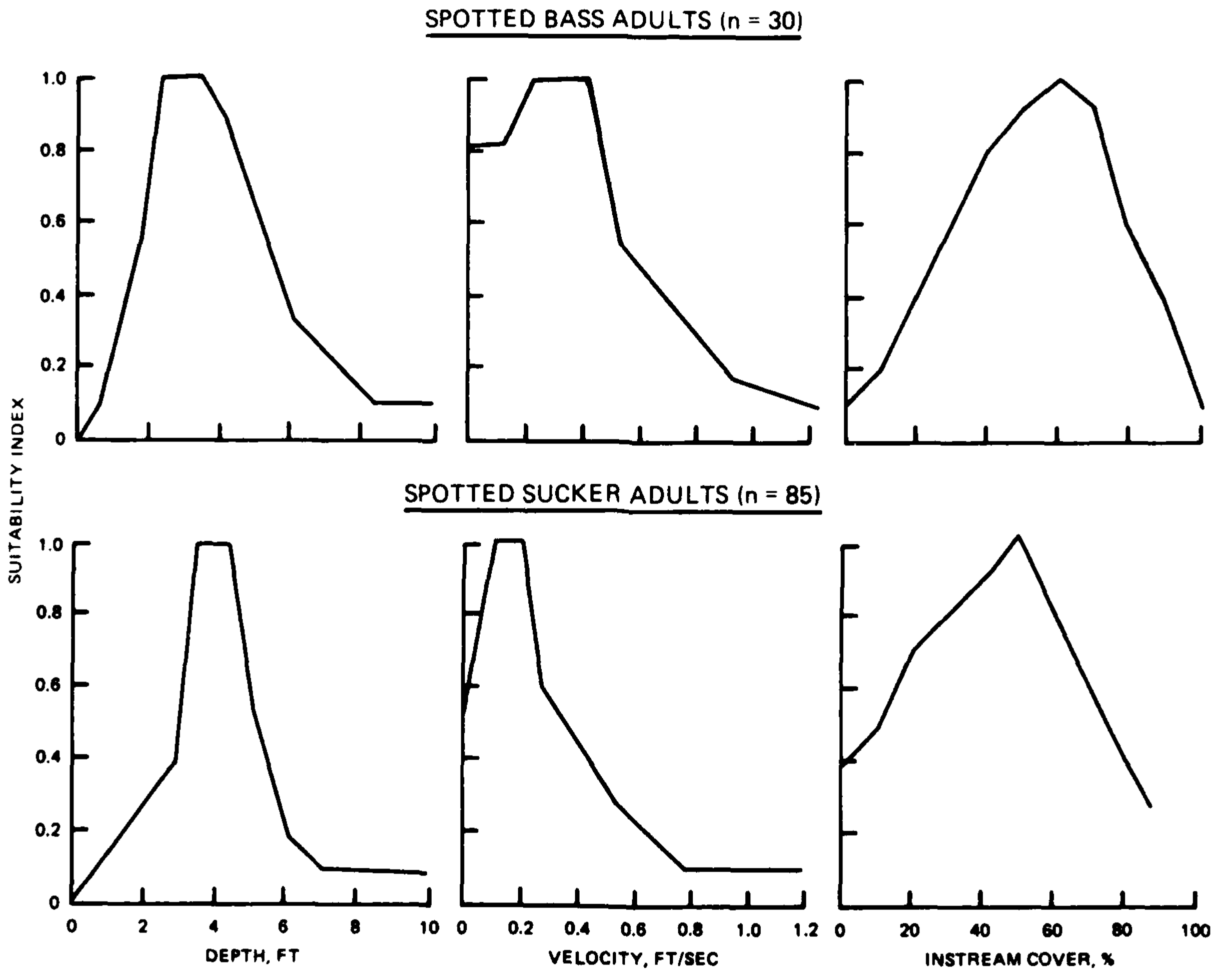


Figure F1. Suitability Index Curves for spotted bass and spotted sucker adults

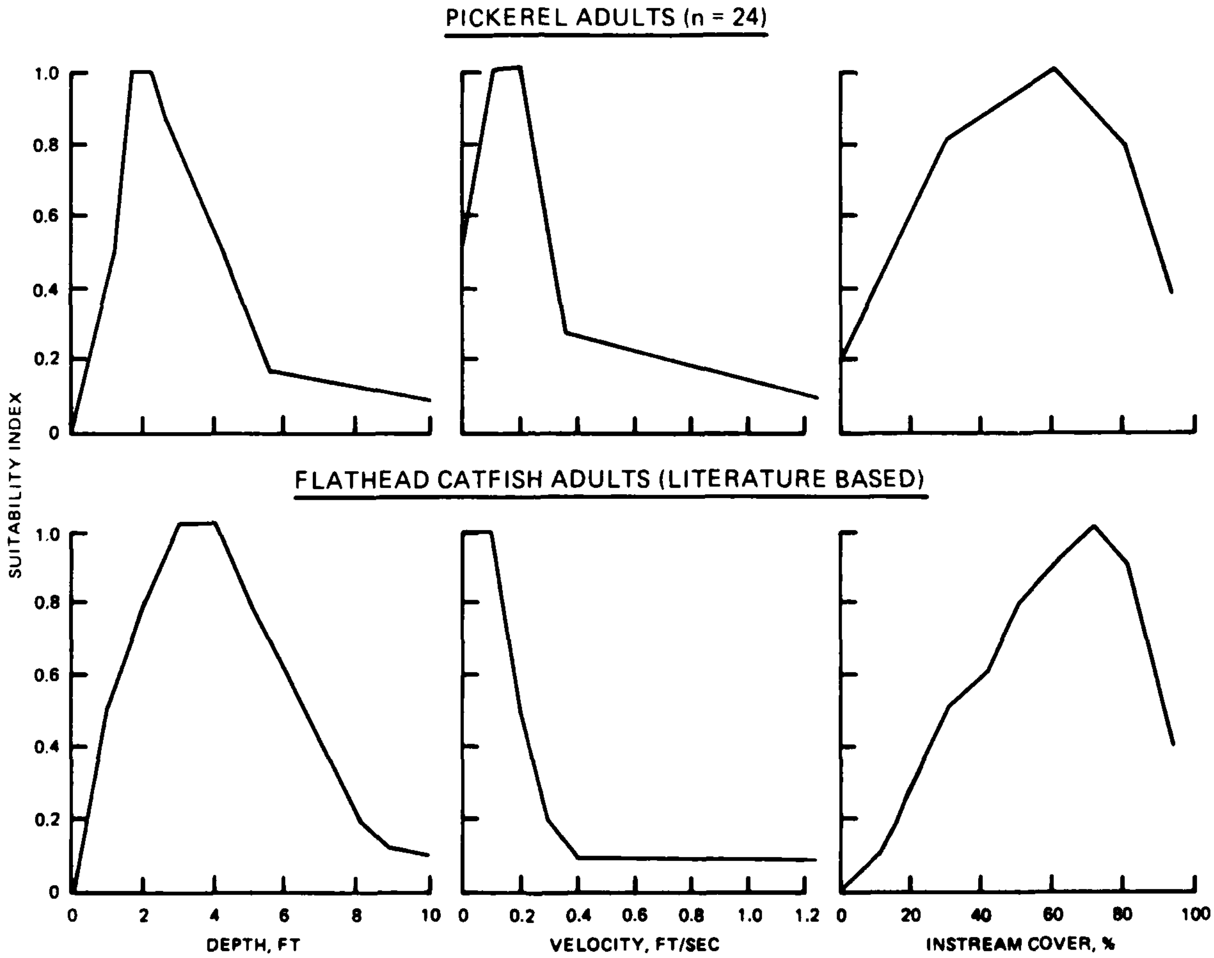


Figure F2. Suitability Index Curves for pickerel and flathead catfish adults

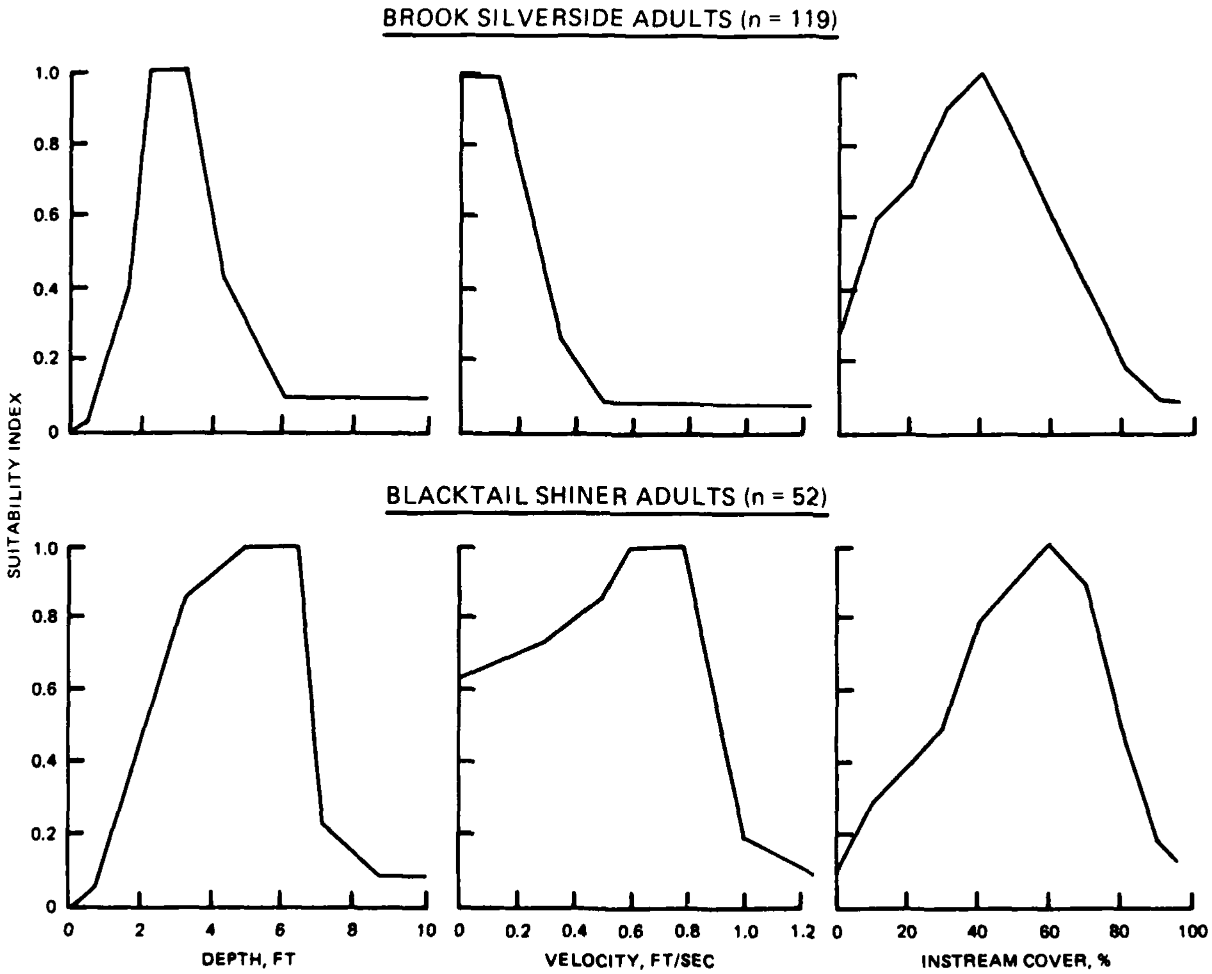


Figure F3. Suitability Index Curves for brook silverside and blacktail shiner adults

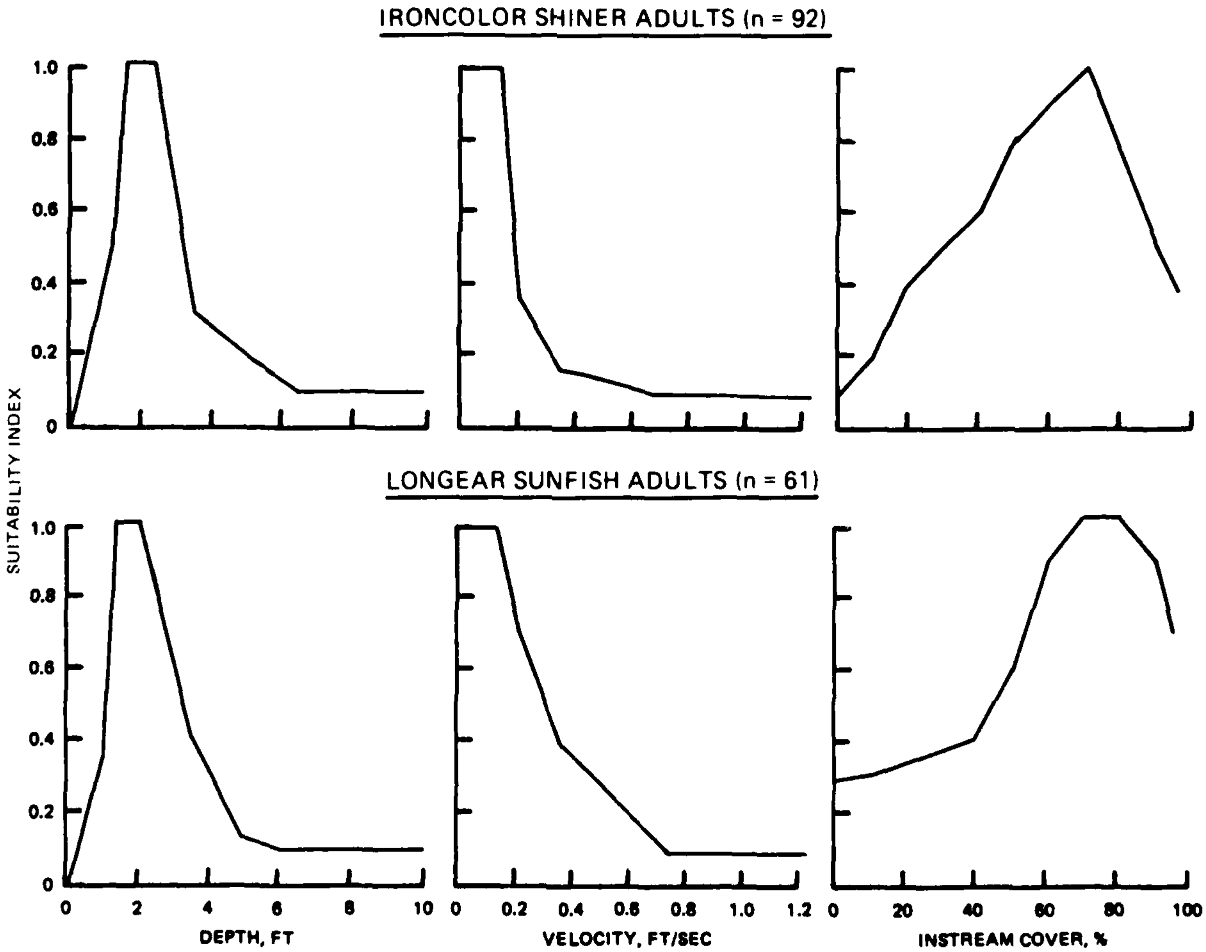


Figure F4. Suitability Index Curves for ironcolor shiner and longear sunfish adults

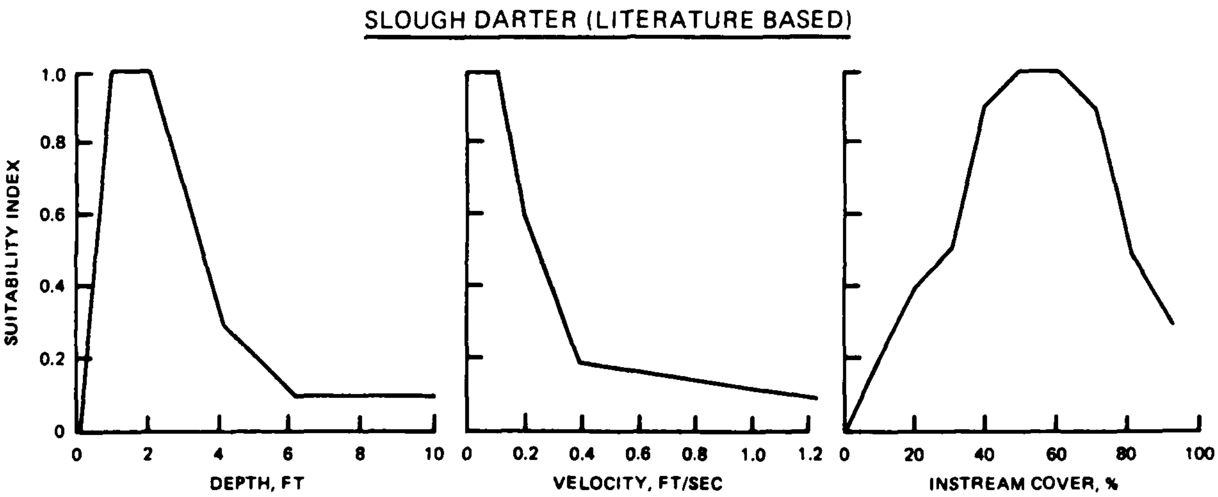


Figure F5. Suitability Index Curves for slough darter

Appendix G: Description of Hydraulic Analysis to Predict Physical Habitat at Unmeasured Flows

1. The purpose of this appendix is to describe the procedure to determine the value of the physical habitat variables (depth, velocity, and cover) and other morphometric features for unmeasured flow conditions in the Little Cypress Bayou. These data are used to calculate HU's to determine maintenance and compensation flows.

2. The first step is to estimate the coefficient of roughness (n) and calculate the slope of the channel (Se) using field data. These values remain constant and are used to determine velocity for unmeasured flows. The coefficient of roughness ranges from 0.025 for clear and straight river channels to 0.150 for weedy and overgrown channels (Bovee and Milhous 1978, Henderson 1966). The coefficient of roughness used in the Little and Black Cypress bayous was 0.075. Once n has been estimated, the slope is calculated from the following equation:

$$Se = \frac{n^2 V^2}{2.22\ R^{4/3}} \qquad \text{(G1)}$$

where

V = mean channel velocity measured in the field, ft/sec

n = coefficient of roughness

$$R = \text{Hydraulic Radius} = \frac{\text{Area, ft}^2}{\text{Wetted Perimeter, ft}}$$

The values to calculate hydraulic radius (area and wetted perimeter) are determined from the graphs (Figure 2). Velocity is then calculated for each cell using Manning's equation expressed as follows:

$$V\text{, ft/sec} = \frac{1.486}{n} R^{2/3} Se^{1/2} \qquad \text{(G2)}$$

The calculated velocities are compared with the field-measured velocities to check the accuracy of the variables used in Manning's equation. If the

velocities do not agree, the slope is adjusted. In most cases, either no or small changes in the slope were required for this study. Once the cell velocities were determined, cell discharge was expressed as follows:

$$Q = V \cdot A \tag{G3}$$

where

Q = discharge, cfs

V = velocity, ft/sec

A = area, ft^2

The cell discharges were summed to obtain a channel discharge that corresponded to the stage height on the graph (Figure 2).

3. Tables G1 and G2 illustrate the steps to determine depth, velocity, and acres of river that occur at the target discharges for the two representative study sites in the Little Cypress Bayou. Target discharges correspond to an incremental range of flows that could be released from the dam. The first step was to calculate the average depth, velocity, and width for each transect at discharges ranging from extreme low flows to overbank flows, using the hydraulic equations and graphs described in the previous paragraph. To accomplish this, new stage heights were drawn on the graph paper (Figure 2). From these graphs, the unmeasured hydraulic components (hydraulic radius and velocity) were determined. Discharge was also calculated for each new stage height. The second step was to calculate regression equations to predict the average depth, velocity, and width for a given discharge. The regression equations were then used to predict average depth, velocity, and width at target discharges of 10, 50, 100, 200, 300, 400, 500, and 1,000 cfs. For cover, a plot was made that related the percentage of cover (i.e., percentage of cells with cover) and discharge for each cross section. An average percentage of cover at each target discharge was then tabulated for each river. These data provided a depth, velocity, and percent cover at each discharge and at each representative site that was used to determine the HSI value. The fourth step was to determine the acres of river that occurred at each discharge by multiplying width times river miles. The final step was to calculate HU's for the study area at each target discharge using the method described in paragraph 12 (Table G3).

Table G1

Procedure to Determine Average Depths, Velocities, and Channel Widths over a Range of Flows Using the Hydraulic Geometry Information from the Graphs. Field Data Was Collected from the Little Cypress Bayou at Hwy 154

Step 1: Calculate average depth, velocity, and width for each transect at 4 discharges.

Downstream Transect				Upstream Transect (Approximately 530 ft Upstream of Downstream Transect)			
Discharge cfs	Channel Width ft	Depth, ft $\bar{x} \pm SD(n)$	Velocity ft/sec $\bar{x} \pm SD(n)$	Discharge cfs	Channel Width ft	Depth, ft $\bar{x} \pm SD(n)$	Velocity ft/sec $\bar{x} \pm SD(n)$
20	51	1.0 ± 0.61(6)	0.30 ± 0.13(6)	9	41	1.8 ± 0.62(4)	0.11 ± 0.03(4)
81	66	2.2 ± 0.92(7)	0.49 ± 0.15(7)	81	60	5.3 ± 1.90(6)	0.23 ± 0.08(6)
232	93	3.1 ± 1.70(10)	0.62 ± 0.26(10)	200	95	6.6 ± 3.90(9)	0.25 ± 0.13(9)
449	230	3.7 ± 2.20(13)	0.69 ± 0.30(13)	556	430	6.8 ± 5.10(20)	0.27 ± 0.14(20)

Step 2: Calculate regression equations to predict the average depth, velocity, and width for a given discharge.

Downstream Transect		Upstream Transect	
Depth, ft = Q (0.006) + 1.39	R^2 = 0.86	Depth, ft = Q (0.007) + 3.7	R^2 = 0.51
Velocity, ft/sec = Q (0.0008) + 0.37	R^2 = 0.82	Velocity, ft/sec = Q (0.0002) + 0.17	R^2 = 0.52
Width, ft = Q (0.36) + 29.3	R^2 = 0.93	Width, ft = Q (0.74) − 0.06	R^2 = 0.96

Step 3: Using the regression equations, calculate the average depth, velocity, and width between the upstream and downstream transects over the discharges of interest. Plot percent cover and discharge for each transect and take the average.

Discharge cfs	Depth, ft Downstream Transect +	Upstream Transect ÷ 2 =	Average	Velocity, ft/sec Downstream Transect +	Upstream Transect ÷ 2 =	Average	Width, ft Downstream Transect +	Upstream Transect ÷ 2 =	Average	Cover percent
10	1.4	3.7	2.6	0.37	0.17	0.27	33	30	32	20
50	1.7	4.0	2.8	0.41	0.18	0.29	50	37	43	25
100	2.0	4.4	3.2	0.45	0.19	0.32	71	74	73	33
200	2.5	5.0	3.7	0.53	0.21	0.37	112	148	130	52
300	3.1	5.7	4.4	0.61	0.23	0.42	153	222	187	60
400	3.7	6.4	5.1	0.69	0.25	0.47	194	296	245	65
500	4.2	7.1	5.6	0.77	0.28	0.52	236	370	303	70
1000	7.1	10.5	8.8	1.20	0.38	0.79	442	740	591	80

Step 4: Calculate the acres of river that the two transects represent over the discharges of interest. This site represents 7.3 river miles. Use the following equation to obtain acres: Acres, ft^2 = [Width × (miles × 5,280)] × (2.296×10^{-5}).

Discharge, cfs	Acres
10	28
50	38
100	66
200	115
300	165
400	217
500	268
1,000	523

Table G2

Procedure to Determine Average Depths, Velocities, and Channel Widths over a Range of Flows Using the Hydraulic Geometry Information from the Graphs. Field Data Was Collected from the Little Cypress Bayou at Mile .

Step 1: Calculate average depth, velocity, and width for each transect at 4 discharges.

Downstream Transect				Upstream Transect (Approximately 530 ft Upstream of Downstream Transect)			
Discharge cfs	Channel Width ft	Depth, ft $\bar{x} \pm SD(n)$	Velocity ft/sec $\bar{x} \pm SD(n)$	Discharge cfs	Channel Width ft	Depth, ft $\bar{x} \pm SD(n)$	Velocity ft/sec $\bar{x} \pm SD(n)$
[illegible]	28	1.8 ± 1.1(3)	0.16 ± 0.07(3)	8	86	1.1 ± 0.45(8)	0.07 ± 0.02(8)
44	64	3.0 ± 1.9(6)	0.19 ± 0.08(6)	82	123	3.8 ± 1.2(12)	0.17 ± 0.04(12)
[illegible]	124	3.7 ± 2.3(12)	0.23 ± 0.09(12)	225	147	5.8 ± 2.3(15)	0.22 ± 0.06(15)
[illegible]	350	4.3 ± 3.0(19)	0.25 ± 0.13(19)	398	250	7.0 ± 3.3(19)	0.25 ± 0.09(19)

Step 2: Calculate regression equations to predict the average depth, velocity, and width for a given discharge.

Downstream Transect		Upstream Transect	
Depth, ft = Q (0.008) + 2.25	$R^2 = 0.82$	Depth, ft = Q (0.014) + 1.90	$R^2 = 0.89$
Velocity, ft/sec = Q (0.0003) + 0.17	$R^2 = 0.88$	Velocity, ft/sec = Q (0.0004) + 0.103	$R^2 = 0.82$
Width, ft = Q (1.14) + 3.41	$R^2 = 0.96$	Width, ft = Q (0.40) + 80.5	$R^2 = 0.95$

Step 3: Using the regression equations, calculate the average depth, velocity, and width between the upstream and downstream transects over the discharges of interest. Plot the percentage of cover and discharge for each transect and take the average.

	Depth, ft			Velocity, ft/sec			Width, ft			
Discharge cfs	Downstream Transect +	Upstream Transect ÷ 2 =	Average	Downstream Transect +	Upstream Transect ÷ 2 =	Average	Downstream Transect +	Upstream Transect ÷ 2 =	Average	Cover percent
10	2.3	2.0	2.15	0.17	0.10	0.14	15	84	50	35
50	2.6	2.6	2.60	0.18	0.12	0.16	60	100	80	40
100	3.0	3.3	3.15	0.20	0.14	0.17	117	120	119	50
200	3.8	4.7	4.30	0.23	0.19	0.21	231	160	196	60
300	4.6	6.1	5.40	0.26	0.23	0.25	345	200	272	68
400	5.4	7.6	6.50	0.29	0.27	0.28	459	240	349	73
500	6.2	9.0	7.60	0.32	0.31	0.32	573	280	426	78
1,000	10.1	16.1	13.00	0.47	0.52	0.50	1,142	479	810	80

Step 4: Calculate the acres of river that the two transects represent over the discharges of interest. This site represents 13 river miles.

Discharge, cfs	Acres
10	79
50	126
100	187
200	309
300	429
400	550
500	671
1,000	1,276

Table G3

Habitat Suitability Index Values and Habitat Units for the Evaluation Species in the Little Cypress Bayou

Site/Discharge		Total Acres Each Reach	Spotted Bass		Spotted Sucker		Brook Silverside		Blacktail Shiner		Ironcolor Shiner		Longear Sunfish		Pickerel		Flathead Catfish		Slough Darter	
			HSI	HU's	HSI	HU's	HSI	HU's	HSI	HU's	HSI	HU's	HSI	HU's	HSI	HU's	HSI	HU's	HSI	HU's
Little Cypress	Mile 2*																			
	10	79	0.76	60	0.62	49	0.80	63	0.65	51	0.76	60	0.89	70	0.89	71	0.68	54	0.74	58
	50	126	0.86	108	0.75	94	0.82	103	0.70	88	0.62	78	0.77	97	0.89	113	0.71	89	0.68	86
	100	187	0.90	168	0.93	168	0.89	166	0.76	142	0.56	105	0.66	123	0.86	161	0.75	140	0.60	112
	200	309	0.93	287	1.0	309	0.54	167	0.81	250	0.38	117	0.59	182	0.68	210	0.67	210	0.50	154
	300	429	0.65	279	0.60	257	0.35	150	0.81	347	0.28	124	0.38	163	0.33	142	0.61	262	0.42	180
	400	550	0.62	341	0.36	198	0.28	154	0.76	418	0.27	137	0.34	187	0.27	137	0.49	269	0.33	181
	500	671	0.62	362	0.34	228	0.22	148	0.48	322	0.26	174	0.34	228	0.24	168	0.38	255	0.34	228
	1,000	1,276	0.31	395	0.26	332	0.17	217	0.38	485	0.20	268	0.22	281	0.16	204	0.21	268	0.20	255
Little Cypress	Hwy 154**																			
	10	28	0.67	19	0.46	12	0.45	13	0.52	15	0.38	11	0.45	13	0.48	13	0.38	11	0.38	11
	50	38	0.74	28	0.53	20	0.53	20	0.58	22	0.38	13	0.43	16	0.52	20	0.38	14	0.42	16
	100	66	0.79	52	0.65	43	0.49	32	0.65	43	0.32	21	0.46	30	0.58	38	0.43	28	0.46	30
	200	115	0.89	102	0.79	91	0.50	57	0.80	92	0.33	38	0.50	57	0.55	63	0.45	45	0.33	38
	300	165	0.86	142	0.69	114	0.33	54	0.86	142	0.30	49	0.39	64	0.41	68	0.38	63	0.35	58
	400	217	0.63	137	0.50	108	0.29	63	0.96	208	0.32	69	0.27	59	0.26	56	0.38	82	0.20	54
	500	268	0.49	131	0.40	107	0.19	51	0.90	241	0.21	56	0.25	67	0.23	62	0.38	102	0.21	56
	1,000	523	0.23	120	0.17	89	0.17	89	0.39	204	0.20	105	0.18	94	0.16	84	0.26	136	0.20	105
Little Cypress	Damsite to mouth†																			
	10	107	--	79	--	61	--	76	--	66	--	71	--	83	--	84	--	65	--	69
	50	164	--	136	--	114	--	123	--	110	--	91	--	113	--	133	--	103	--	102
	100	253	--	220	--	204	--	198	--	185	--	126	--	153	--	199	--	168	--	142
	200	424	--	389	--	400	--	224	--	342	--	155	--	239	--	273	--	255	--	192
	300	646	--	421	--	371	--	204	--	489	--	173	--	227	--	210	--	325	--	238
	400	767	--	478	--	306	--	217	--	626	--	206	--	246	--	193	--	351	--	237
	500	939	--	493	--	335	--	199	--	563	--	230	--	295	--	230	--	357	--	284
	1,000	1,799	--	515	--	421	--	306	--	689	--	373	--	375	--	288	--	404	--	360

* Represents 13 river miles.
** Represents 7.3 river miles.
† Represents 20.3 miles.

Appendix H: Composite Habitat Unit--Discharge Table for the Little and Black Cypress Bayous

Discharge cfs	Habitat Units	
	Little Cypress Bayou	Black Cypress Bayou
0	300	200
10	654	440
50	1,025	575
100	1,595	759
200	2,469	986
300	2,658	1,154
400	2,860	1,213
500	2,986	1,326
1,000	3,730	1,699

Appendix I: Habitat Unit Duration Table for the Cypress Bayou Basin HEP Study

Month/Site	Habitat Unit Duration Values, percent*																	
	10%		20%		30%		40%		50%		60%		70%		80%		90%	
	HU	Flow	HU	Flow	HU	Flow	HU	Flow	HU	Flow	HU	Flow	HU	Flow	HU	Flow	HU	Flow
Little Cypress: Mile 1-Damsite																		
January	3,670	900	3,375	670	3,060	530	2,850	390	2,655	290	2,420	190	2,035	155	1,500	90	1,020	45
February-March	4,080	1,200	3,740	1,050	3,450	740	3,260	640	2,965	485	2,810	360	2,650	285	2,500	215	2,000	155
April-May	4,300	2,000	3,775	1,075	3,380	670	3,000	510	2,795	370	2,600	270	2,200	175	1,500	90	1,025	50
June	3,500	760	2,990	510	2,500	215	2,000	155	1,600	105	1,300	75	1,011	40	805	12	580	8
July	2,575	265	1,730	110	1,250	60	1,000	30	850	14	565	7	520	6	350	2	300	0
August-October	2,000	155	1,275	65	810	13	725	11	654	10	400	3	350	2	325	1	300	0
November	3,000	510	2,500	215	1,775	125	1,400	85	1,250	60	990	16	800	12	600	8	375	3
December	3,690	930	3,175	610	2,820	375	2,420	190	2,180	170	1,805	130	1,450	88	1,110	55	950	15
Black Cypress: Mile 0-Damsite																		
January	1,900	1,300	1,705	1,050	1,510	730	1,315	480	1,120	280	975	190	910	170	856	140	800	120
February-March	1,940	1,325	1,800	1,200	1,660	940	1,520	740	1,379	570	1,238	420	1,100	270	975	190	880	145
April	2,500	2,000	1,847	1,250	1,629	900	1,410	600	1,193	370	1,000	210	942	180	882	145	800	120
May-December	1,883	1,270	1,648	930	1,413	600	1,179	340	985	180	914	170	850	135	675	75	564	45
June	1,750	1,150	1,333	500	982	180	890	150	816	130	589	55	530	30	450	11	350	4
July	860	140	600	60	566	45	531	30	492	20	416	7	343	4	284	2	242	1
August-October	900	160	511	25	443	10	427	8	296	3	277	2	258	1	239	1	200	0
November	1,632	910	1,106	275	920	175	825	130	610	65	563	45	513	25	455	12	343	4

* Percent of time habitat unit (HU) is equalled or exceeded at the given flow (cfs).

Appendix J: Habitat Units Lost from Inundation in the Little Cypress Bayou. The Value of Variables Used to Calculate the HSI Were Determined from the Hwy 154 Downstream Transect According to Table G1

Species	Monthly Discharge (cfs)* /Acres																							
	January 149/211		February 253/305		March 298/346		April 206/262		May 193/252		June 45/114		July 6/79		August 2/76		September 2/76		October 3/76		November 33/104		December 92/158	
	HSI	HU	HSI	HU	HSI	HU	HSI	HU	HSI	HU	HSI	HU	HSI	HU	HSI	HU	HSI	HU	HSI	HU	HSI	HU	HSI	HU
Spotted bass	0.79	167	0.79	241	0.65	225	0.76	199	0.77	149	0.67	76	0.62	49	0.62	47	0.62	47	0.62	47	0.67	70	0.79	125
Spotted sucker	0.49	103	0.60	183	0.49	169	0.48	126	0.43	83	0.40	46	0.32	25	0.36	27	0.36	27	0.36	27	0.40	42	0.42	66
Brook silverside	0.43	91	0.37	113	0.34	117	0.41	107	0.41	79	0.45	51	0.38	30	0.38	29	0.38	29	0.38	29	0.41	43	0.45	71
Blacktail shiner	0.79	167	0.90	274	0.90	311	0.89	233	0.82	158	0.56	64	0.52	41	0.52	39	0.52	39	0.52	39	0.56	58	0.73	115
Ironcolor shiner	0.49	103	0.40	122	0.37	128	0.42	110	0.42	81	0.37	42	0.36	28	0.45	34	0.45	34	0.45	34	0.37	38	0.37	58
Longear sunfish	0.48	101	0.42	128	0.34	117	0.38	99	0.41	79	0.43	49	0.43	34	0.49	37	0.49	37	0.49	37	0.43	45	0.49	77
Pickerel	0.45	95	0.43	131	0.42	145	0.45	118	0.43	83	0.62	71	0.60	47	0.60	46	0.60	46	0.60	46	0.62	64	0.65	103
Flathead catfish	0.42	89	0.45	137	0.46	159	0.43	113	0.42	81	0.32	36	0.31	24	0.39	30	0.39	30	0.39	30	0.33	34	0.36	57
Slough darter	0.45	95	0.39	119	0.38	131	0.41	107	0.43	83	0.46	52	0.46	36	0.58	44	0.58	44	0.58	44	0.46	48	0.56	88
Total	--	1,011	--	1,448	--	1,502	--	1,212	--	876	--	487	--	314	--	333	--	333	--	333	--	442	--	760

* Monthly discharge corresponds to the 50-percent exceedance flow at USGS gage at Hwy 259 near Ore City.

END
8-87
DTIC